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ORBITAL ELEMENTS FOLLOWING PREMATURE TRANSLUNAR INJECTION SHUTDOWNS

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MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

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PROJECT APOLLO

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SUMMARY

This note presents an investigation of the orbital elements following premature S-IVB shutdowns during the nominal AS-504 translunar injection (TLI) maneuver. The orbital elements at shutdown are compared to those at various true anomalies later in the orbit. The results show that the instantaneous orbital elements vary considerably during a coast following a shutdown that occurs late in the translunar injection burn.

INTRODUCTION

The nominal AS-504 translunar injection maneuver consists of a 328-second S-IVB burn which increases the spacecraft's velocity by more than 10 000 fps. At shutdown the spacecraft is injected on an initial ellipse with an apogee of 315 000 n. mi. and period of 18 1/2 days. However, the burn is nominally targeted so that, if no maneuvers are performed during the coast, the spacecraft will pass very close to the Moon and return to Earth with acceptable entry conditions. The actual trajectory, therefore, is greatly perturbed during its pass by the Moon and differs considerably from the initial ellipse. This actual circumlunar trajectory has an apogee of 215 000 n. mi. and a period of approximately 6 days.

If a premature shutdown occurs during the nominal burn the orbit can vary from nearly circular to highly eccentric ellipses, depending on the S-IVB burn time. As the apogee altitude increases and the spacecraft passes nearer the Moon, one would expect the orbital changes due to the Moon's gravitational attraction to increase. Similarly, as the orbital period becomes larger and the velocity near apogee becomes relatively low, the effect of the Sun's perturbations would be expected to become more evident. This study was made to determine how the orbital elements vary for premature S-IVB shutdowns occurring at different times in the S-IVB burns.

ANALYSIS

The nominal AS-504 TLI burn is the basis for this study. The osculating orbital elements of primary interest are the perigee altitude, h_p, and perigee velocity, V_p. Integrated values of h_p and V_p were calculated at specific shutdowns in the nominal burn using three combinations of perturbation to learn the predominant perturbation on the trajectory:

1. Integration including Earth oblateness and Sun and Moon effects.

2. Integration including Earth oblateness and Sun effects.

3. Integration including only Earth oblateness.

Conic values of h_p and V_p (i.e., the values at cutoff) were compared to the integrated values.

Figure 1 shows the conic and integrated values of h_p and V_p for orbits resulting from premature shutdowns. Close agreement exists for shutdowns prior to 300 seconds of S-IVB burn, which corresponds to an orbital eccentricity of 0.85. For shutdowns during the final 28 seconds of the burn, the perturbations of the Sun and the Moon are reflected in the substantial differences between conic and integrated results. The integrated "no Moon" curve that considers only Earth oblateness and Sun effects is similar to the integrated curve considering these two as well as the Moon's effect. (However, a lag exists with respect to time of S-IVB shutdown.)

Figure 2 shows the integrated values for h_p and V_p that consider Earth oblateness and Sun and Moon on a larger scale to indicate the considerable variation which occurs for shutdowns during the nominal AS-504 TLI burn.

Figures 3(a), (b), and (c) show how the instantaneous perigee varies during the coast following three different S-IVB shutdowns. In addition to the integrated curve and integrated "no Moon" curve, a curve is included which shows the perigee variation due to the Earth oblateness only. From figure 3 it can be seen that the predominant perturbation is due to the Moon and its greatest effect is later in the TLI shutdown range.

CONCLUSIONS

It is shown that the h_p and V_p predicted at engine shutdown is very accurate for shutdowns during the first 300 seconds of the 328-second nominal AS-504 TLI burn, regardless of the method of calculation. For shutdowns during the final seconds of the burn, however, the instantaneous orbits during the following coast vary considerably and, therefore, conic h_p and V_p predicted at shutdown and the actual integrated h_p and V_p are different.

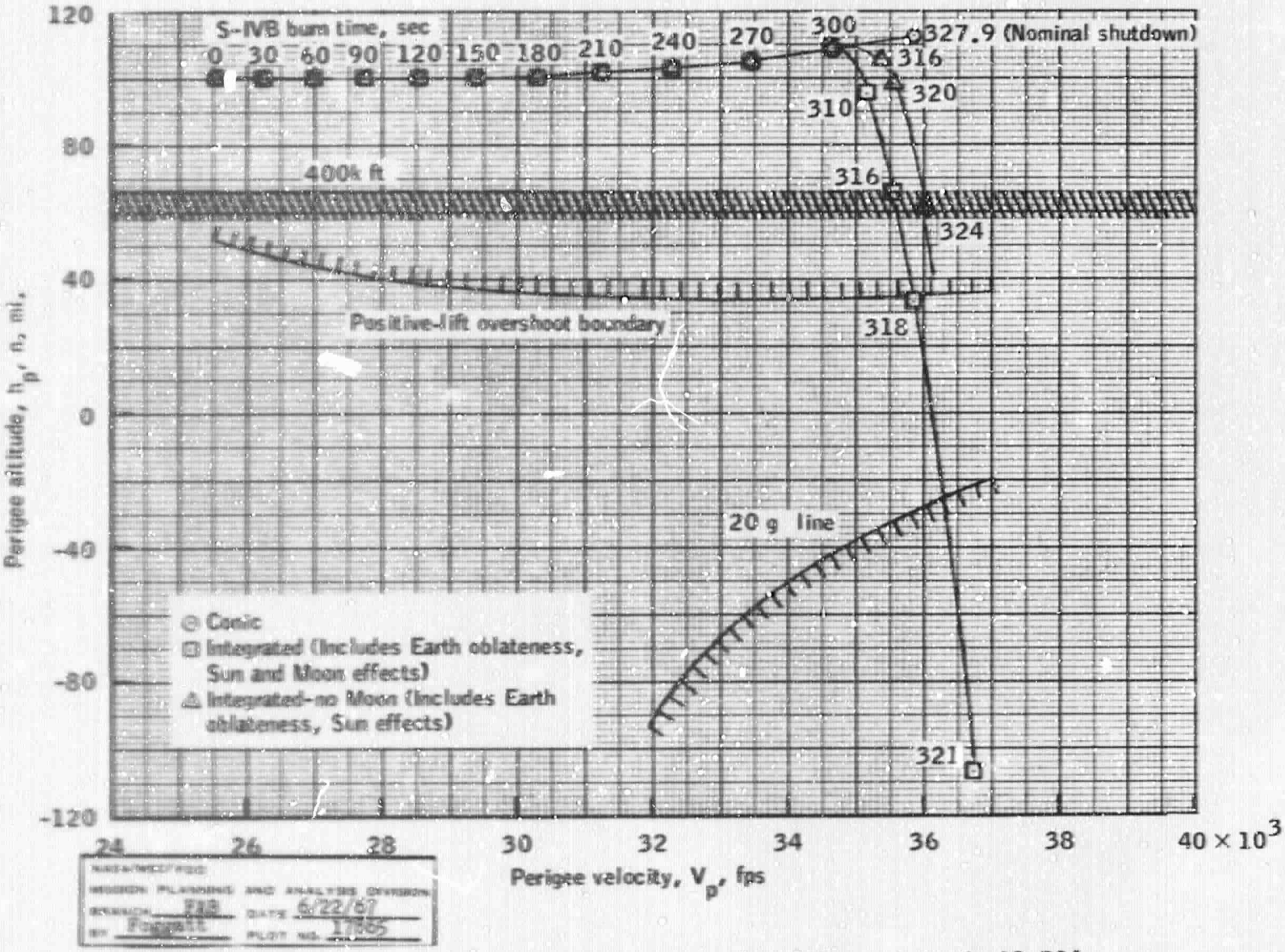


Figure 1.- Comparison of conic and integrated data for shutdowns during the AS-504 nominal translunar injection burn.

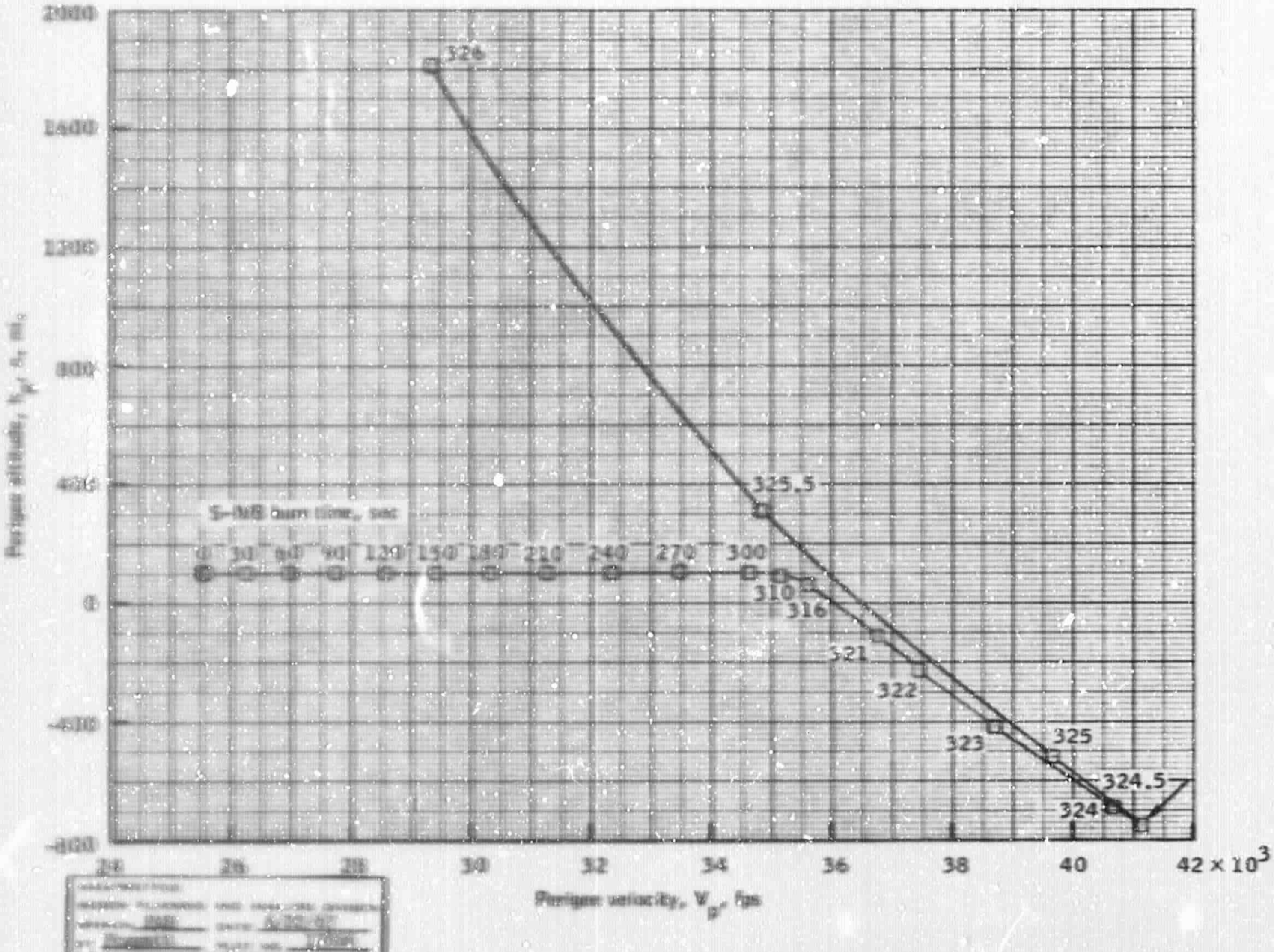
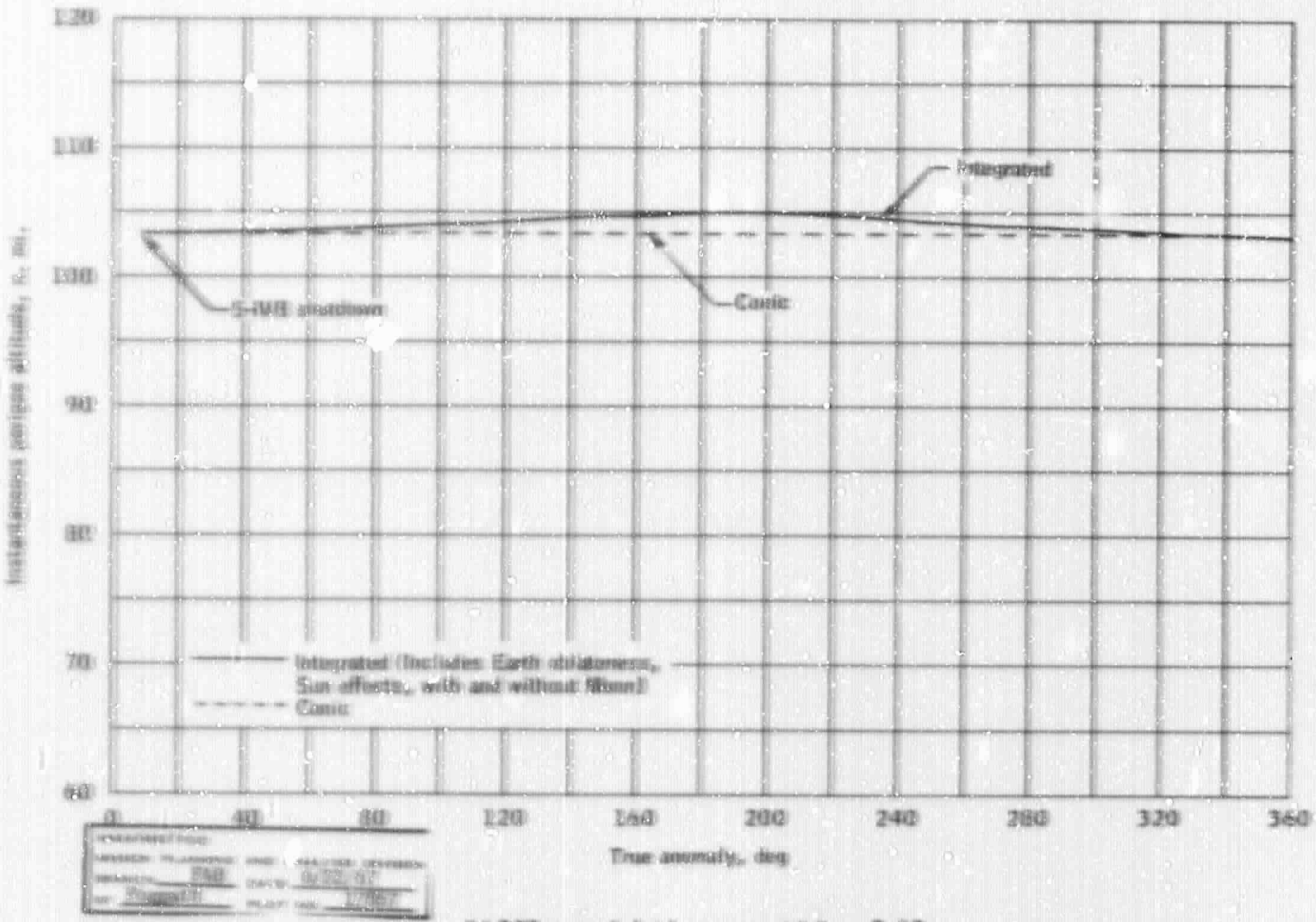
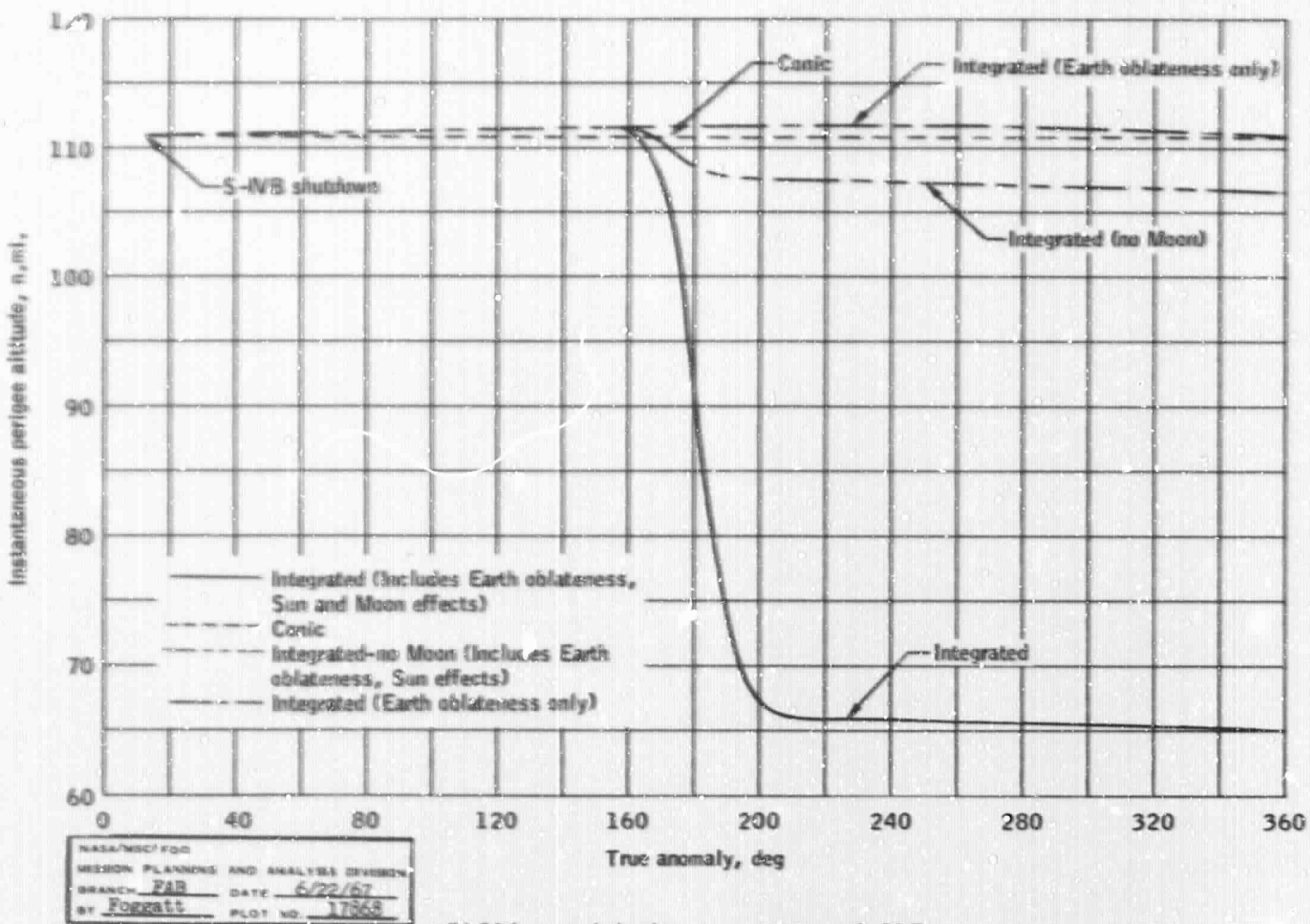


Figure 2. - Integrated data for shutdowns during the AS-504 nominal translunar injection burn (including earth oblateness, sun and moon perturbations).



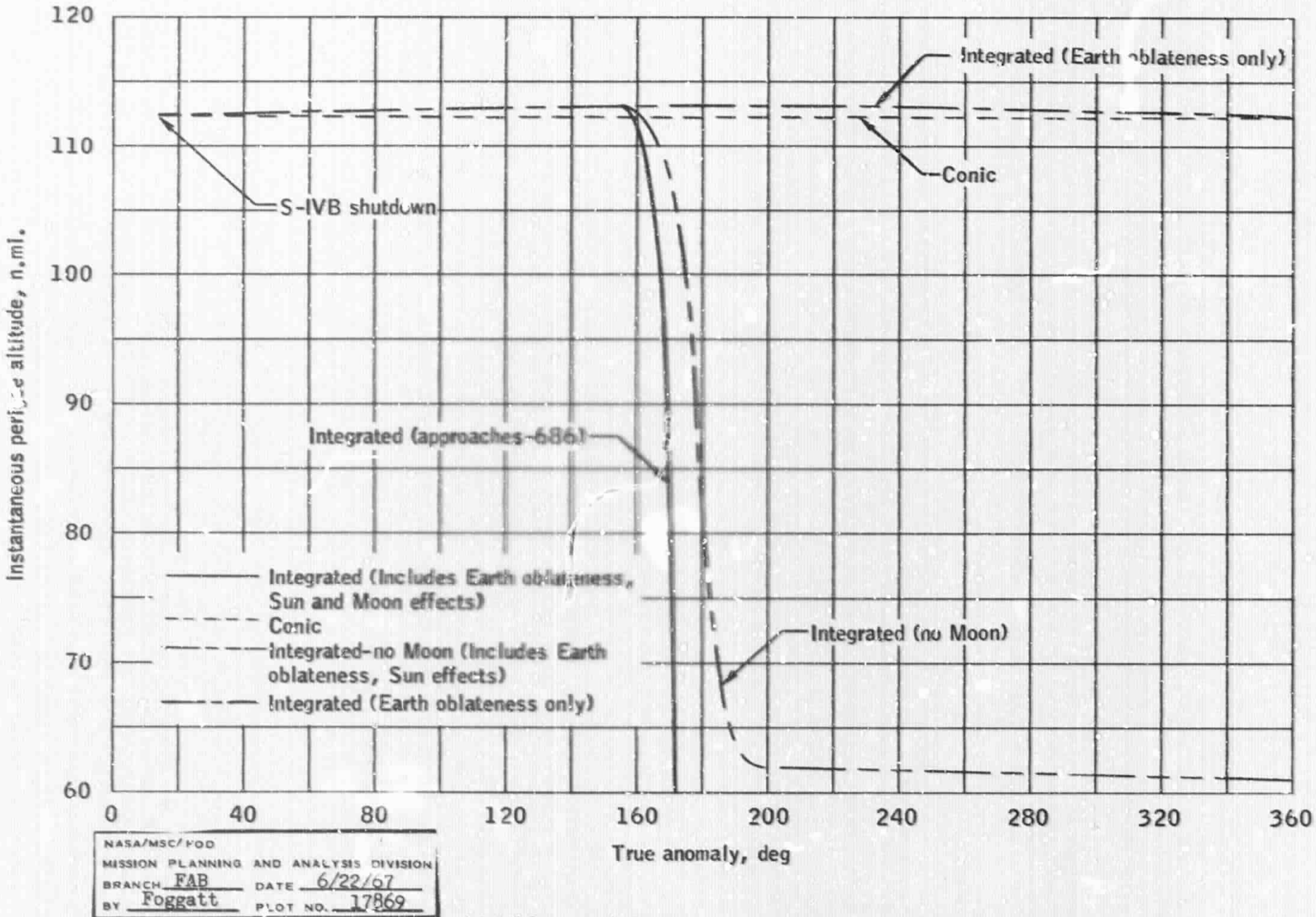
(a) 240-second shutdown, eccentricity = 0.60.

Figure 3.- Comparison of conic and integrated data following premature S-IVB shutdown.



(b) 316-second shutdown, eccentricity = 0.917.

Figure 3.- Continued.



(c) 324-second shutdown, eccentricity = 0.957.

Figure 3.- Concluded.